CONVERSATIONAL TECHNIQUES IN THE STUDY AND PRACTICE OF EDUCATION

Br. J. educ. Psychol., 46, 12-25, 1976

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By G. PASK
(*System Research Ltd., Richmond, Surrey*)

SUMMARY. Conversational theory is an attempt to investigate the learning of realistically complex subject matter under controlled conditions. To do this it is necessary to insist on restricted definitions of common terms such as understanding and to demand more stringent conditions before accepting that it has been demonstrated. These conditions can be achieved if the subject matter is structured and the student follows certain rules in demonstrating understanding. Computer linked systems have been developed which control and record student learning. The systems provide the experimenter with detailed records of the learning strategies used by students and the student with learning experiences which normally ensure understanding.

INTRODUCTION

THE intention of this paper is to introduce some of the basic ideas and techniques used in a series of recent investigations of learning involving realistically complex learning materials. It has proved impossible to give a full description here, and this may lead to misunderstandings about both the theory and the methods used. However, the ideas have been developed more fully elsewhere (Pask, 1975a, 1975b) and further details may be obtained from the author.

The starting point is the idea that the fundamental unit for investigating complex human learning is a conversation involving communication (see McCulloch, 1965) between two participants in the learning process, who commonly occupy the roles of learner and teacher. In an experimental situation, such as that used, for example, by Piaget, one of the participants is the experimenter who plays a less active role than that of teacher. Evidence of learning may come from comments or answers from the learner, or from the use of materials which demonstrates understanding more unambiguously than do verbal responses. In the research reported here the mental processes used by the learner in reaching an understanding of a topic are exteriorised by providing apparatus which controls his learning and also allows records to be made of the steps taken.

An essential part of the apparatus is a subject matter representation—a diagram of the relationship between concepts which need to be grasped before the topic as a whole can be fully understood. The student is provided with materials and practical demonstrations to help him understand the concepts and relationships and is allowed to explore the concept structure with a good deal of freedom, provided certain fundamental principles are not violated. The student progresses through his learning sequence generally by making a series of electrical contacts which show, by means of lights, what are his immediate learning tasks. The electrical contacts are also linked to a computer which monitors and records the steps taken. The computer thus provides a permanent record of the learning strategies adopted by the student and also prevents the student from making forbidden moves or attempting to go further than his present level of understanding allows. This procedure provides an effective learning environment for the student and also data for the research worker which allows him to examine learning strategies which are normally only accessible through introspection (as in the work described by Marton and Säljö in the previous paper).

These experimental methods represent an entirely different research procedure from those commonly used in investigating human learning. Conventional laboratory investigations (such as those by Wason, 1968) and factor-analytic studies (Guilford, 1960) provide important evidence about certain types of intellectual activity or structure, but it is argued that conversational theory, as developed later in this paper, provides important evidence about how students learn realistic bodies of subject matter over appreciable intervals.

In fact, the theory takes us much further than that. It permits the investigation of other important, but elusive, aspects of human learning which have educational implications—notably, the nature and control of understanding; the nature and use of analogical concepts; learning style; innovation; and learning to learn. The chief drawback is that it becomes necessary, in developing conversational theory, to redefine common terms (such as understanding) to have a restricted and more precise meaning and also to introduce new terms in describing the operation of the apparatus used in these studies. These various terms are italicised when they are introduced and the sense in which they are being used is explained. Another problem in describing this approach to learning is that it no longer is possible to make a clear distinction between learner and teacher in describing the two participants in the conversation which leads to learning. It soon becomes clear that the brain of the person who is learning can operate in two distinct modes which can be viewed as 'teacher' (directing attention to what needs to be done) and 'learner' (assimilating the subject matter), when a student is using structured learning materials and appropriate heuristics.

It is, of course, risky to set up a new theoretical structure. Most traditional theories are well founded in experimental work and have demonstrated their value in some applied fields. However, the current approach rarely, if ever, contradicts well established ideas on learning; rather it reinterprets them in a way which has greater educational utility and which also unifies ideas and evidence derived from other experimental procedures. Conversational theory basically sets up a system within which to view learning. In this it resembles the information processing approach to perception and learning described by Broadbent (1957, 1971), Miller *et al.* (1960) and Welford (1968). The methods adopted however, draw from a wide variety of approaches. It makes use of, for example, the experimental procedures and ideas of Piaget (e.g., Flavell, 1963; Vygotsky, 1962; and Luria, 1961); personal construct theory (Kelly, 1955); transactionalism (Laing *et al.*, 1966 ; Bateson, 1972) ; behaviourism ; and eclectic functionalism (Bartlett, 1932; Poulton, 1953). Moreover, conversation theory accommodates the structural psychology of Scandura (1973) and, as a bonus, can draw on ideas from the fields of artificial intelligence and computer-aided instruction.

Previous research using conversational techniques.

The techniques of observation and recording of conversations in the study of learning are not, in themselves, new. The themes pervading conversation theory have been voiced repeatedly. There are also methodological precedents in the approaches of Piaget of Vygotsky, or Papert (1970) which represent conversational methods for probing, observing and exteriorising normally hidden cognitive events—notably, the 'paired experiment' and the 'questioning interview.' Both techniques rely upon a participant experimenter in the role of a tutor, interviewer or interrogator, who shares in the mental activity of the respondent but who still obeys certain pre-specified, though conditional, rules.

Several aspects of these methods are of special interest: the eliciting of explanatory responses, the notion of agreement between participants, and the representation of thoughts and discoveries. The problem situation is embodied in a physical artefact, such as a puzzle, a mechanical gadget, or else a concrete situation (water jars, metric rods and other means of depicting conservation of quantity, volume, etc.). Whatever the apparatus may be, it is jointly perceived by the participants (respondent and experimenter) and is open to external observation.

The experimenter poses problems (some of them designed to place insuperable obstacles in the respondent's path) concerned with the function of the artefact or extensions of its function. The respondent replies, either verbally or by manipulating the artefact. Typically, the questions involve 'How' and 'Why' and the answers, if forthcoming, are explanations or constructive responses. Since some enquiries are designed to pose insoluble problems, the respondent sometimes appeals for help and, in this case, the experimenter performs a demonstration or points out a principle or suggests some way in which the artefact could be modified. All explanations, whether verbally uttered or not, can be interpreted in relation to the problem situation. Thus, the participants are able to reach an agreement and the basis for their agreement is exteriorised for impartial scrutiny. Parallels with conversational theory will subsequently become apparent.

THE DEVELOPMENT OF CONVERSATIONAL THEORY

Conversational theory, as already stated, represents a systems approach to learning. It has certain basic postulates and definitions through which its properties are described. Learning is seen as taking place through **interpreted formal relationships**, such as 'next,' 'adjacent,' 'periodic,' 'dual,' 'sum,' or 'product.' These formal relationships are interpreted in terms of a context (societal, electrical, mechanical, statistical) and appear as sets of connected propositions (physical laws, social theories) which will be called **topics**. The specific meaning of this, and subsequent terms, must be noted. The **concept** of a topic is seen as a way of satisfying the relationships embodied in that topic, rather than simply a stored description. Similarly, a **memory** of a topic becomes a procedure which reconstructs or reproduces concepts. Within conversation theory learning develops through **agreements** between the participants which subsequently lead to **understanding** by the learner. Again the terms have a specific meaning which depends on the apparatus used for controlling learning and demonstrating understanding.

In normal conversation understanding of a topic is demonstrated if the learner provides a verbal explanation of its meaning in accord with an accepted standard definition. In the typical Piagetian experiment understanding is demonstrated by both verbal and non-verbal means. The experimenter questions the child, but also observes manipulations of the apparatus, and ultimately agrees that a valid explanation is given. In our own work, extensive use is made of modelling facilities in which the student's model building behaviour provides non-verbal explanations of a topic and thus exteriorise some of his thought processes. While agreement can be reached at a verbal level between student and teacher and is a necessary condition for understanding, within conversational theory additional evidence of understanding is required. Not only must the student be able to describe the concept (which may reflect only rote or temporary learning), he must also be able to use the underlying relationships by operating on appropriate apparatus to demonstrate understanding.

A concept of, say *T*, has been defined as an internal procedure which brings about and satisfies *T*. The procedure is a class of what may be thought of as 'mental programs' which satisfy the relationships embodied in *T* and there will be many ways, using a modelling facility, in which *T* can be represented. 'Teacher' and 'student' may choose different ways of representing *T* in practical terms, but the concepts will be equivalent if both representations, when executed, lead to the same outcome, or satisfy the same relation. **Agreement** will then have been reached about the concept, but understanding may still not have been satisfactorily demonstrated.

Within conversational theory **understanding** depends on the ability to reconstruct the concept of *T*. The only demonstrably stable or permanent concepts in the memory are seen as those which can be reconstructed *ab initio* by applying certain common cognitive operations to topics which are initially understood. For the present it is convenient to group a variety of cognitive operations under a single term '**discovery**' (Belbin, 1969). This 'shorthand notation' carries with it a recognition that the underlying mental operations are psychologically and formally distinct, and that students will differ in their competence to use different kinds of 'discovery' operations.

To ensure that a demonstration of understanding is unambiguous it is required to be carried out in a particular way, using modelling facilities in conjunction with a subject matter representation which summarises the relationship between topics within the subject matter. This leads to the next crucial part of conversation theory—that the student should see in advance the 'map of knowledge' through which he is to work.

Subject Matter Representation.

In the Piagetian interview or the paired experiment, the participant experimenter probes the respondent in order to draw out his concepts of the problem situation—for example, by asking why or how an event takes place, or what would happen if some feature of the situation changed. In this type of learning the experimenter must have a comprehensive knowledge of the learning **domain** to provide appropriate corrective assistance. The experimenter can thus be assumed to have a mental 'map' of the subject matter, against which to compare respondent's responses. Such an internal representation of knowledge has the defect that only the verbalised parts brought out through the conversation are made accessible to the respondent, or to an external observer. It seems clear that there must be great advantages in providing **both** participants with an external representation of the subject matter through which topics can be identified and discussed. In this way, explanation can be initiated by either participant.

Allying this idea to the earlier formal definitions of concepts and topics, it becomes necessary to develop a network of topics and concepts which represent the chosen subject matter area. It is also necessary to ensure that the formal relationships between the concepts are made explicit within the network. The final network within which the student works is called an **entailment structure**, which is developed initially from discussions with a subject matter specialist and later through working out more precisely the logical relationships involved.

The starting point is a thesis on the chosen subject area expounded usually by a subject matter expert, although it can be done by a student. The thesis is then broken down into a series of derivations bringing out the various topics, concepts and relationships involved. Each topic relation stands for a class of valid explanations of the topic, or it can be thought of as a series of abstract programs which would satisfy the topic relation if they were compiled and executed. Again, to meet the requirements of the narrow meaning of **understanding,** the entailment structure developed must have the type of ' cyclicity ' which allows a student to reconstruct a concept and also have ' consistency,' implying that all the topics can be separately identified and connected by derivation paths.

Development of an entailment structure.

The techniques which have been developed for enabling subject matter specialists to expound a thesis within the constraints imposed by conversation theory involve interaction with a computer which stores the information already provided and also provokes the expositor(s) to further clarification of the underlying relationships. It is important to stress that the resulting structure, describing say ' optics,' is merely the expositor's thesis on optics. It is not ' optics ' in any ideal sense; the thesis represents only the personal construction of one or more expositors.

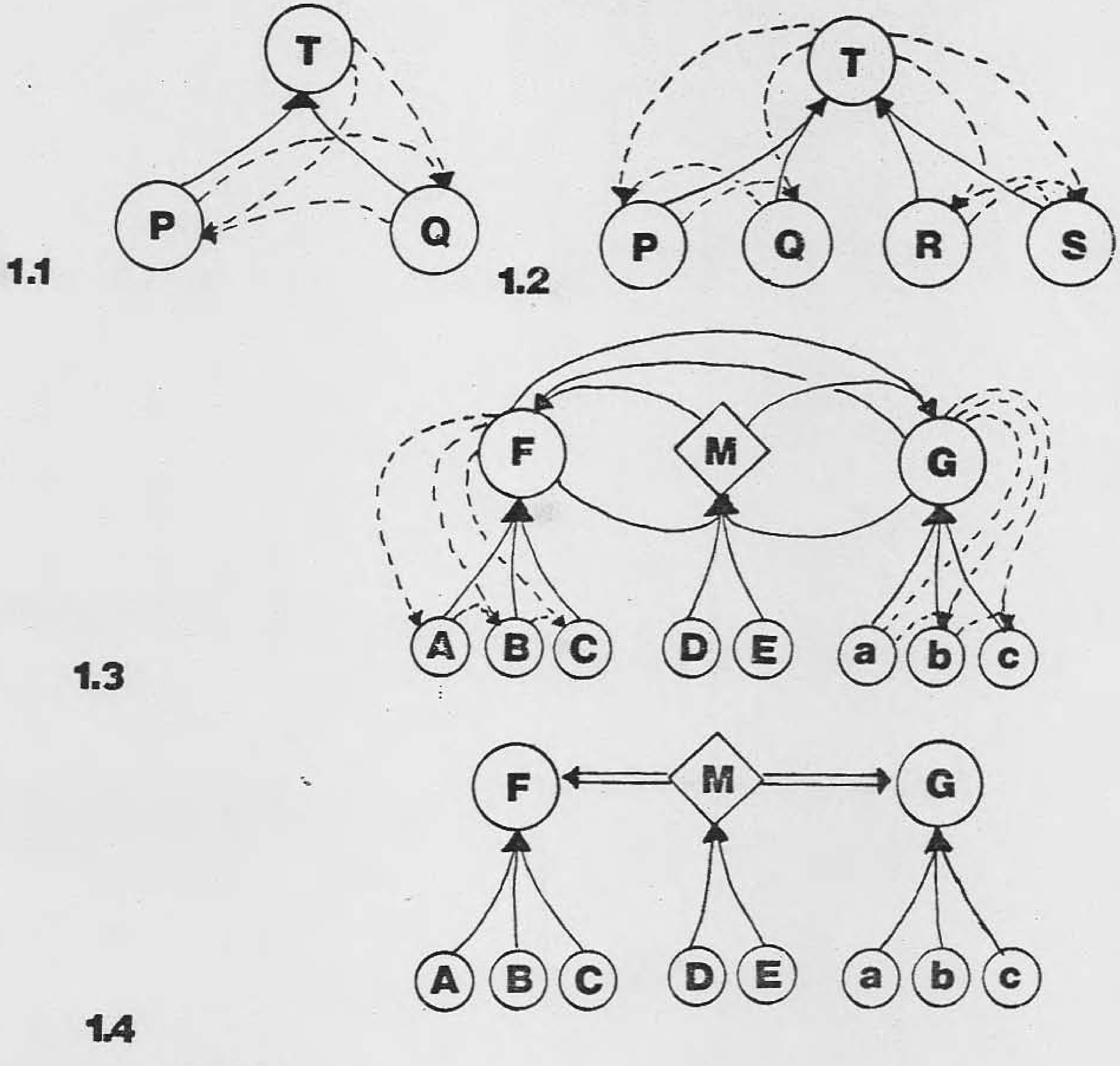
Initially the subject matter specialist is required to cite topics which are involved in his thesis—say *P*, *Q*, *R*, *S* and *T*. Next he is asked to construct a thesis on the assumption, which is later checked, that he can explain each topic by saying how it is derived from the others. Suppose his thesis is that *T* is derivable from *P* and *Q*. In terms of conversation theory, this means that an explanation of *T* can be derived from an explanation of *P* and *Q*, provided that the student is capable of the cognitive operations which have been labelled **discovery**. The expositor's derivation is accepted if, and only if, an explanation of *P* and *Q* can also be derived from the explanation of *T*. This requirement provides the necessary cyclicity or ' getting back ' property which can later be used to demonstrate understanding.

There may be, and nearly always are, different ways of deriving *T*—from *P* and *Q*, say, but also perhaps from *Q*, *R* and *S*. Such derivation paths are kept distinct and are conveniently exhibited to the expositor in the form of a diagram, or directed graph, in which the **nodes** stand for topics, the **arcs** for parts of a derivation and the **arc clusters** (e.g., the pair of arcs linking *P* to *T* and *Q* to *T*) for derivation paths. Figure 1.1. shows the structure ' *T* derived from *P*. *Q*,' while Figure 1.2 shows ' *T* derived from *P* and *Q* or from *R* and *S*.'

The term **entailment** is used as shorthand for the whole relation represented by " derivable from . . . given the necessary cognitive operations involved in discovery." To codify entailment it is necessary at least to discriminate between axiomatic, purely formal, derivations and **correspondences** (morphisms, such as isomorphism) which depend upon the potential, but not yet identified, universes of interpretation. For example, no such distinction is shown in Figures 1.1 or 1.2, but one does appear in Figure 1.3 (which is explained in simplified form in Figure 1.4 and its footnotes) where electrical and mechanical universes of interpretation are identified.

As a thesis is expounded under the constraints demanded to maintain cyclicity and consistency, its representation burgeons into an expanded version showing a whole series of topics (nodes) and inter-connecting lines (arcs). At this stage the diagram is called an **entailment mesh,** which must later be simplified and tightened up to form the final entailment structure. As the mesh develops the expositor is urged to expand the thesis by saying what the peripheral topic relations are, and these additions cause the mesh to widen and produce more interconnections between topics.

FIGURE 1



DERIVATIONS.

1.1. topic T derived from topic P and topic Q.

1.2. topic T derived from topic P and topic Q, or from topic R and topic S.

1.3. a correspondence, M, between topics F and G, depending upon D and E (see explanation below).

1.4. a shorthand notation for Figure 1.3. when interpreted (see text) to represent an analogy.

One plausible interpretation of Figs. 1.3 and 1.4 is as follows :

F = Mechanical Oscillator.
G = Electrical Oscillator.
A = Mass.
B = Friction.
C = Elasticity.
a = Inductance.
b = Resistance.
c = Capacitance.
D = Properties (predicate name) distinguishing electrical and mechanical universes.
E = laws of simple harmonic motion.
M = Analogical Topic containing the formal similarity (E) which is common to F and G as well as the class of property—value distinctions (D is only one of any) which express differences essential to any analogy relation.

At this stage the structure, as stored by the computer, contains nodes with names, but only a ' formal ' or abstract meaning. Subsequently the expositor provides adjectives or **descriptors** which give ordinary meaning to the topics within the entailment mesh. But, once this is done, we move away from the abstract graph, towards the practical descriptions of the concepts later developed within the ancillary modelling facilities.

Most studies which employ explicit representation of subject matter take it for granted that a description is given and understood by the participants. Commonly, this description is just sensibly chosen, as in Bruner, Goodnow and Austin's (1956) study of concept acquisition. Sometimes it is based upon a factor analytic resolution of semantic scales, as in Osgood's (1962) semantic differential techniques. Among the exceptions to this rule is work by Thomas (1970) and his associates in which exploratory conversations, often concerned with learning, are based upon mutually generated descriptions. Such descriptions are obtained from one respondent (here an expositor) by applying the repertory grid sampling procedure technique (Bannister and Mair, 1968) to elicit descriptors and their values which are Kelly's (1955) ' personal constructs.' If the situation warrants serious attention to the description (construct) schemes of several expositors a more sophisticated routine, exchange grids (Thomas, 1970), is used to compare individual views and obtain a mutually shared description.

Within conversational theory we opt for descriptors that are personal constructs and which are also compatible with the formal structure already laid out. (This approach allows students to become expositors.) The description process can be shown briefly by the following stages:

(1) The expositor chooses a **head node** which is the topic he believes his thesis is about. Many head nodes may be produced in the formation of an entailment mesh, as expositors often recognise the ' true ' head node fairly late in the process.

(2) The mesh is now pruned (by removing the dotted ' back linkages ' in Figure 1) to yield a structure that is hierarchical apart from the introduction of correspondences (as in Fig. 1.4) which become analogy relations, once they are interpreted.

(3) The putative analogies are ordered and groups of them are used as though they were ' objects ' in repertory grid administration. Each group of nodes is used to generate at least one construct (or descriptor name) having real values (+, −; or rating scale numerals) that discriminate the topics which are related by the analogy and the value NULL (' * ' or ' irrelevant ') on the analogy itself. For example, in Figure 1.4 the descriptor name, ' Scientific Discipline ' may be entered as D and has values ' Electrical ' and ' Mechanical ' on topics F and G (electrical oscillator ' and ' mechanical oscillator ') D is the difference part of an analogy relation (node M). The systemic or formal similarity preserved by the analogy is expressed by the equations for simple harmonic oscillation (node E). All constructs so far elicited are given values on all the nodes (as in rating constructs over all the objects in a set, not just the triple selected for construct elicitation in Kelly's approach).

(4) The process continues until all topic nodes can be uniquely identified.

(5) At this stage the main descriptors divide up into independent universes of interpretation for each of which an independent part of the modelling facility is required. The lowermost nodes, which refer to a particular part of the modelling facility, specify the kinds of formal relations that are to be modelled in it when (non-verbally) explaining topics with nodes at a superordinate position in the hierarchy. For example, in Figure 1.4, two partitions of the modelling facility are required—one is a simple 'electricity bench,' while the other is a simple 'mechanics bench' both of which would be found in any school physics laboratory. In this case, it is necessary to model both electrical circuits and mechanical devices (with springs, weights, and so on), some of which act as simple harmonic oscillators.

(6) The entire pruned and described entailment mesh now created forms the **Entailment Structure.**

(7) Finally the expositor is required to do what was originally described as necessary, namely to use the modelling facility, which has now been specified, to express the class of valid explanations for each topic of the Entailment Structure in a standard form which can be represented unambiguously in a computer. Perhaps the most suitable name for such a standard form of explanation is a **behaviour graph** (BG) meaning the (many different) prescriptions for building models that act as non-verbal explanations; **not** to be confused with the behaviour produced if the model is executed (either externally, in the facility, or 'internally' in the student's brain). Elsewhere, the BG has been termed a **task structure.**

The Conversational Domain.

The result of the efforts of the expositors to fulfil the conditions imposed by conversational theory on the description of a thesis is a **conversational domain** (such as that shown in Figure 2), which represents in diagrammatic form the apparatus necessary to explore the relationships between such topics as the laws of simple harmonic motion and the behaviour of electrical and mechanical oscillators (as shown in Figures 1.3 and 1.4). This conversational domain consists of:

(*a*) an entailment structure;

(*b*) the associated collection of BGs indicating acceptable explanations;

(*c*) the modelling facility, partitioned into appropriate universes such as mechanical or electrical apparatus with which to test understanding of topics;

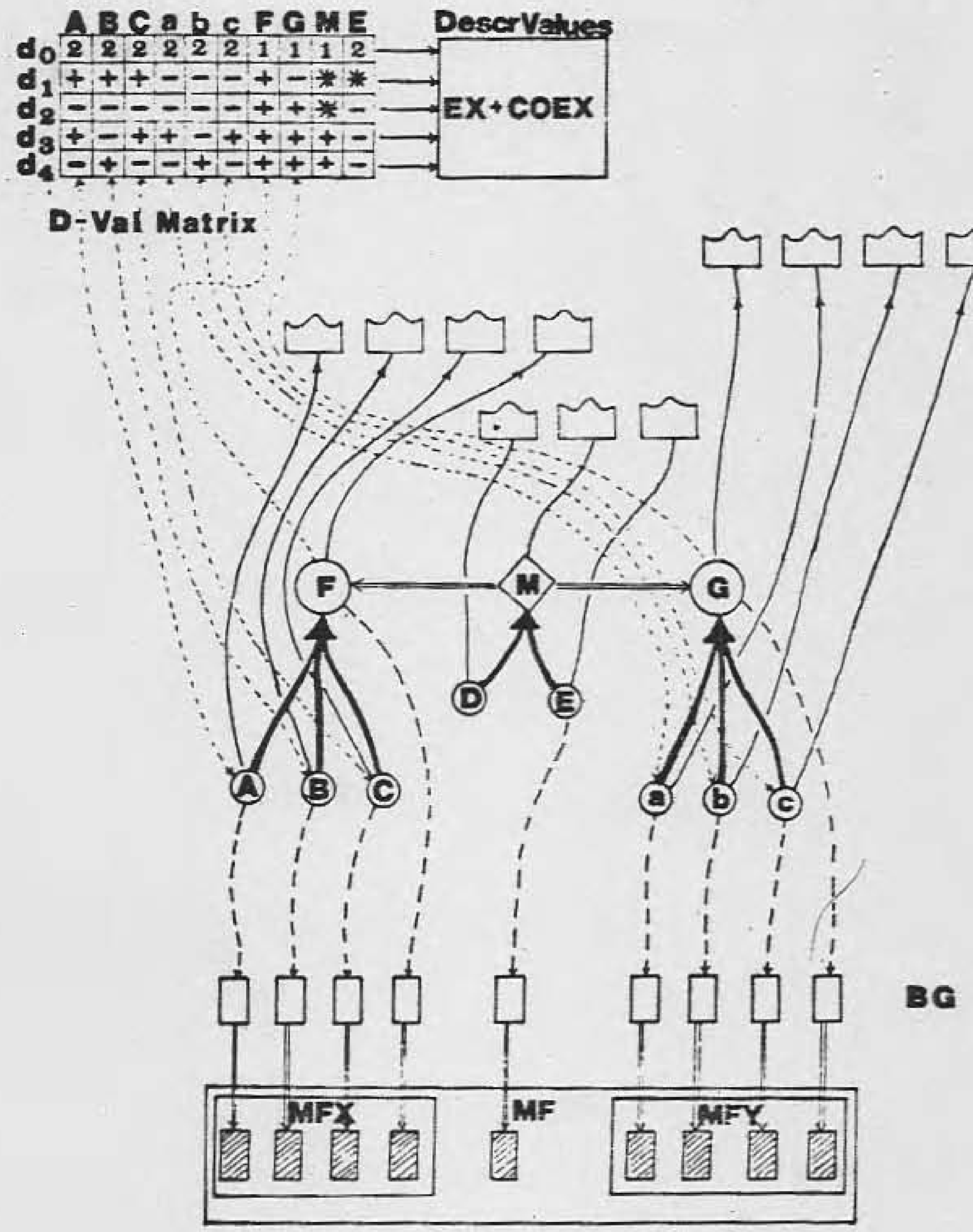
(*d*) descriptors which explain in everyday language the subject matter contained formally and symbolically in the entailment structure;

(*e*) various signalling and information storage arrangements that are attached to the topic nodes (lamps to guide the student, and pulses passed to the computer indicating the step being taken by the student); and

(*f*) examples and counter examples, usually displayed graphically, that provide the context for the descriptors and hence give meaning to the thesis.

The example given in Figure 2 is much simpler than entailment structures used in actual experiments. For example, a thesis on heat engines involved 60 nodes; reaction kinetics involved 180, meiosis and mitosis 275, probability theory 320, while the maximum used so far has been 500 nodes (statistics).

FIGURE 2



Topic nodes **F, G, M, A, B, C, a, b, c,** and their connections are part of the entailment structure as it is displayed to the participants in a conversation. Each node is associated with computer storage and coloured lamps which act as state indicators showing transactions or states such as **Explore, Aim, Goal, Working, Understood**. Nodes are accessed by naming conjoint descriptor values and the system picks out a node through descriptor value matrix (assigning descriptor values to nodes). Here we use only the values +, −, * (irrelevant) and 1, 2; in general, descriptors are many valued. Each cell in the matrix is electrically connected via a random access projector to slides presenting example(s)/counterexample(s) (the array EX-COEX). Each node in entailment structure (apart from **D** which is a descriptor name) has an associated behaviour-graph BG, which determines models (shaded rectangles, below BG rectangles) in a modelling facility MF. Thus, the BG of F, A, B, C yield models in MFX (mechanical) and the BG of G, a, b, c, yield models in MFY (electrical). Topic E may be modelled in either part of the facility or as an abstract mathematical equation. Modelling the analogy relation, M, implies building a model in MFX and the properly corresponding model in MFY and relating the models, under execution, so that E-principles are common to both models.

Key to Notation:

□ = Behaviour Graphs BG nodes attached by ——→ link.

▨ = Models (either demonstrations or non-verbal explanations) generated (⟹) from BG.

○, ◇ = Nodes in entailment structure.

= Storage and display arrangements (for **aim**, **goal**, **understand**, etc.) connected by —→— to each node.

←→ = Accessing connections from matrix to nodes and *vice versa*.

Descriptor names and values compatible with the interpretation of this entailment structure suggested in the caption of Fig 1.4.

d_0 = Level = distance from Head. Values 1 or 2.

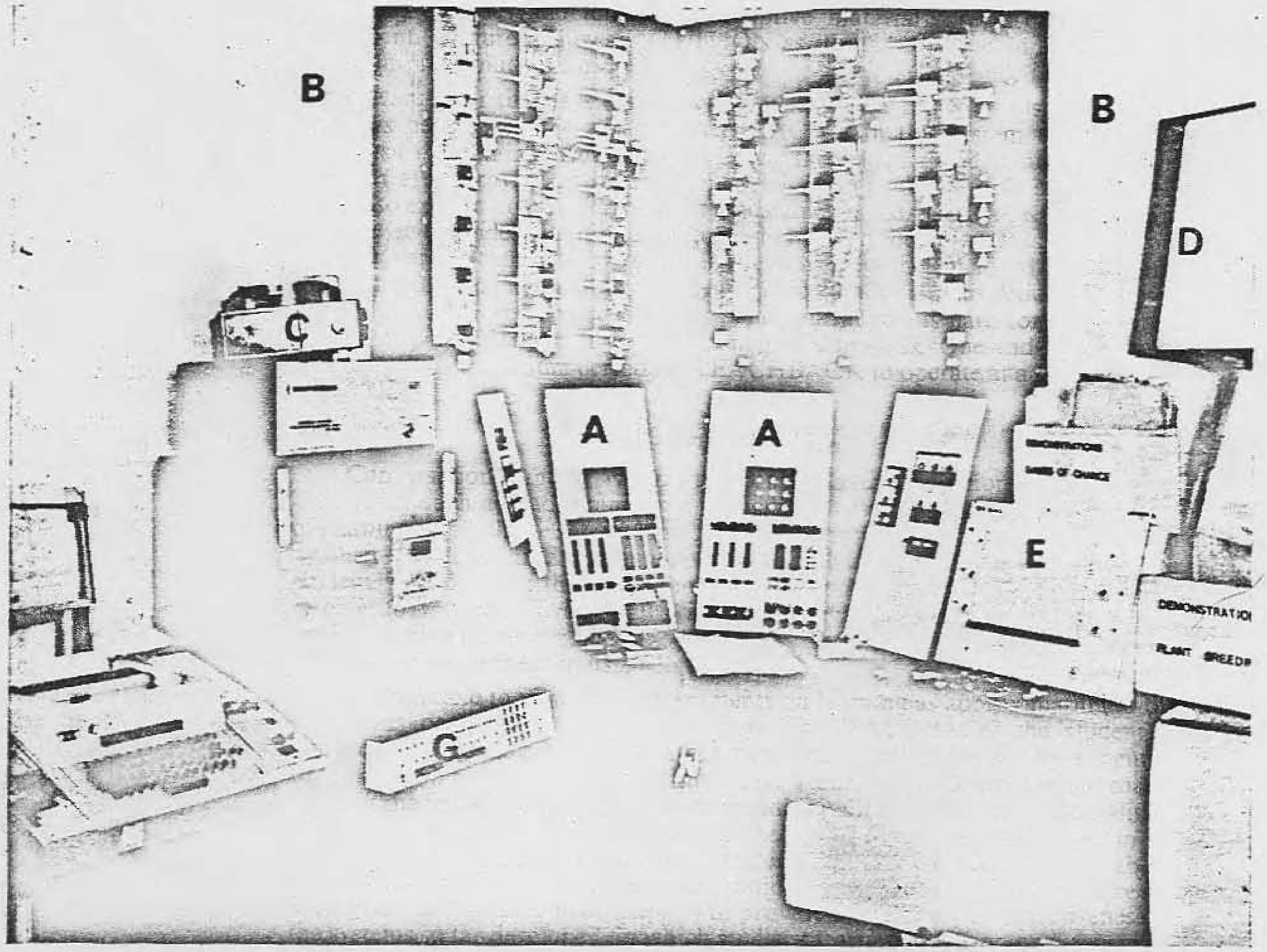
d_1 = **Discipline.** Values, Mechanical (+), or Electrical (−) or irrelevant (*).

d_2 = **Dynamic Periodicity.** Values +, −, or irrelevant(*).

d_3 = **Storage and release of energy.** Values +, −, or *.

d_4 = **Waste or dissipation of energy.** Values +, −, or *.

FIGURE 3



The 'INTUITION' Conversational system as used for learning about 'probability theory.'

A = Modelling Facility for topics in Probability theory: a 'Probability laboratory' in which demonstrations are given by instruction cards laid over fascia and in which non-verbal explanations are elicited.

B = Entailment Structure. Each topic has node with group of 'state' signals. Entailment connections shown by lines and descriptor values by colour and alpha-numeric coded regions.

C = Random Access Projector, Displaying examples and counter examples as required in explore transactions.

D = Screen.

E = Confidence Estimation console and questioning device.

F = Controller and recorder.

G = Minicomputer (can service several student stations).

displayed throughout the learning process, both to A and to B. These diagrams, showing the distributions of explore, aim, goal and understood markers represent learning strategies, which show how the student tackled his attempts to reach and understand his learning goals. Examination of the paths shown in these diagrams have led to the identification of characteristic learning strategies which will be described in a subsequent paper, together with systematic individual differences in competence to learn and discover.

COMPUTER CONTROLLED CONVERSATIONS

In the tutorial condition described so far, B provides the answers to A's questions and gives appropriate demonstrations. His actions may involve help and encouragement, but the basic core of these activities depends only on the conditions imposed by conversation theory within the particular domain being explored. It is thus possible to replace the tutorial arrangement with what is called the **standard experimental condition** in which the tutor's control is handed over to a computer, or to an experimenter who has no teaching function.

Operating in this condition the student is required to accept certain rules. He must:

(*a*) intend to learn the head topic;
(*b*) obey the transaction rules (as described earlier);
(*c*) have only one aim at a time (except those which are being explored);
(*d*) not already understand the head topic; and
(*e*) undertake some transactions until the head topic is finally understood.

Under these conditions the computer is able to direct the student to appropriate information and demonstrations available in pamphlets and on tape/slide presentations. The student can carry out tests of his understanding and the computer will check which of the derivations are correct, in terms of the BG. The student thus progresses as he did with the tutor present and again it is important to realise that the variety of paths and demonstrations available means that students have considerable freedom to learn within the constraints of the system as a whole.

This standard condition shows why it was stressed originally that the distinction between teacher and student can no longer be maintained. In the tutorial arrangement A interacts with B through the conversational domain within the defined restrictions. But under the standard condition what happens? A does not converse with the machine, although the computer checks the moves made. In fact, A behaves in the two ways described earlier. One part of his brain (A_1) works out the moves to be made, asks questions, seeks answers, while another part (A_2) is trying to understand the topics.

Operating System Using Conversational Theory.

To date two pieces of equipment have been developed within which conversational domains can be established. CASTE (Pask and Scott, 1973) is a computer controlled laboratory installation. A portable version, INTUITION, has been used for research in schools and colleges and is relatively inexpensive. Both systems contain a board showing a diagram of the entailment structure with electric sockets at the nodes surrounded by coloured lamps which indicate the transactions being undertaken and the stage the student has reached in learning the topics. The student uses wires to connect sockets according to the rules laid down, and the computer checks that each move is acceptable. The (*e*) Given this information, *A* is also able to indicate the topic or topics he immediately wishes to learn about. The topics *A* desires to learn about are called **goals**; and these are marked with a goal signal to this effect. There may be one goal or several; if there is only one goal it may, in fact, be the aim topic.

(*f*) If *B* is wise he will check *A*'s ability to learn about the selected goals by seeing that: (1) the goals are all situated on allowable paths ; and (2) each permissible goal satisfies the condition that, for at least one derivation path leading to that goal (and usually there are many paths), all immediately subordinate topics in this path are marked as being understood. Any goal satisfying these criteria is called a **working topic** and the goal signal is changed to a working signal.

(*g*) If *A* disputes *B*'s evaluation of his understanding or if no topics are currently marked as understood (which is the starting condition) then *A* can engage in an ' explain and derive ' transaction. First, *A* must show that he can explain the outstanding topic (an *A*, *B* agreement over models for the topic). If so, then *A* must show that he can also explain the immediately subordinate topics on some allowable derivation path. Then the outstanding topic can be marked as understood.

(*h*) All the transactions leading up to the selection of working topics are components of a ' higher level ' agreement, namely, an agreement regarding the derivation of the topic.

(*i*) For any working topic *A* can, if he wishes, attempt a non-verbal explanation. On the other hand, he can request information by asking for example, " How do I explain this topic? " *B* is in a position to reply by recourse to the *BG* of the topic which generates the accepted non-verbal explanations of the topic. These model building behaviours are called **demonstrations** since they are delivered as though by a laboratory demonstrator. After each demonstration, *B* asks *A* the question " How do you explain this topic? " and *B* keeps a record of all the demonstrations so far delivered.

At some stage, either *A* constructs an explanatory model for the topic or else the topic is discarded. Explanation (model building) often involves trials and self-corrected revisions. When *A* is satisfied with his ' final version ' he submits the explanation (or explanatory model) to *B* who checks it to make sure it is not a replica, parrot-wise, of a demonstration already seen by *A*. It is accepted as understanding if this condition is satisfied and if there is 'agreement' in the sense explained earlier.

Generally, the explanations are non-verbal (models) and *B*'s model will be found, like a demonstration, among the *BG* of the topic in hand. Under these circumstances, agreement and correctness are both secured, if both models do, on execution, satisfy the same relation. If so, the topic is marked **understood**. If not, *A* may opt for more demonstrations or revise his approach (**aim** and/or **goal** selection).

The crucial point is that an understanding in the present strong and special sense is determined by a two level agreement: *A* **and** *B* **agree about a derivation and, in the context of this derivation they also agree about an explanation of each topic.**

Once a node is marked as understood, its state does not change during the rest of the conversation. The justification for this rule is our postulate (and experience) that understood topics have concepts that are stable.

(*j*) The transactions which lead up to the ' higher level ' agreement about a derivation are exteriorised, physically, as a series of node-state distributions

TUTORIAL CONVERSATIONS AND TRANSACTIONS

The student using a conversational domain is able to undertake various learning activities or **transactions** either with an experimenter who responds verbally, or by relying on information provided in pamphlets under computer guidance within the framework of the entailment structure. In order to give a clear idea of what might take place in a conversational domain consider a tutorial conversation in which one participant (*B*) is the teacher, while the other (*A*) is the learner.

Participant *A* is ignorant of some of the topics and ultimately intends to learn the head topic. He has access to the modelling facility, the entailment structure, and its description scheme. *B*, in addition, is given access to and control, over the descriptive examples and counter-examples, the various *BG* and the state-markers which indicate the transaction taking place. *B* can take advantage of this polarity to act in the role of a teacher. *B* may use all kinds of acumen; he may learn about *A*, give good advice and so on. All we require is that the assistance he gives and the agreements he reaches are compatible with and derived from the entailment structure and its *BG*.

The following types of transaction may take place:

(*a*) *A* can ask *B* about the values of descriptors in general, and he can point out topics by citing topic descriptions, **i.e.,** combinations of descriptor values. For example, referring to Figure 2, *A* can access the node encoded as *G* by conjoint statements like '**Level** (d_0)=1 and **Discipline** (d_1)=Electrical' or by 'Periodic (d_2=+) and Discipline (d_1)=Electrical' or by any other combination that identifies this node. If he can uniquely point out a topic, he can ask what other descriptors (if any) have other than null values on these topics, and, if so, what the values are. These questions are efforts to make sense of the domain, and if *B* answers the questions by providing examples and counter examples of descriptor values to which he has access, they form part of what are called **explore transactions.**

(*b*) *A* can state his intention to come to grips with any topic that he can point out uniquely, using a combination of descriptor values. Such a statement is an intended immediate aim in learning. If *B* is wise he will check *A*'s sincerity (for *A* might point at topics haphazardly) by determing that *A* appreciates the meaning of the descriptors used to specify the intended aim. Assuming this precaution has been followed, we then refer to the original intention statement as an **aim request.**

(*c*) *B* validates the aim by asking *A* multiple choice questions spanning the values of these descriptors and *B*'s reply is evaluated by confidence estimates over the response alternatives, to questions about the descriptors. If *B*'s certainty about the correct alternatives is high enough to make learning feasible (appropriate indexes, θ^*, are described in Baker, 1969; Shuford *et al.*, 1966; and Dirkswager, 1975), then the topic node is instated as the current **aim**: failing that, *A* is requested to engage in further **explore** transactions to obtain further information and so to increase the value of θ^*.

(*d*) Once an aim is instated, its node is marked by a signal light visible to both *A* and *B*. Then *A* can ask *B* questions like "How am I permitted to learn about the aim topic?" and *B* is in a position to reply either by a gross display of all derivation paths or by delineating permissible derivations from the aim topic to topics which appear lower in the hierarchy and are marked **understood**, or else to topics which are lowest and simplest nodes.

modelling facilities and ancillary descriptive materials are also part of the equipment. Figure 3 shows INTUITION as it has been used in schools for a thesis on probability theory.

A variant of these systems which does involve a tutor has also been used. This has been given the name TEACHBACK. In this system the tutor (*B*) attempts to maintain a neutral role by acting the role of a student and asking the learner (*A*) to provide an explanation of his own for each topic selected. He must also explain how he derived that explanation. TEACHBACK is important because it provides additional information about how students learn from (stilted) verbal transactions, as well as providing the standard behavioural information. The method has been used successfully in conjunction with tests, but only over short learning periods. The neutral role is hard for the tutor to maintain, particularly in large subject-matter domains. One-and-a-half hours has proved the maximum period for TEACHBACK to operate at a time.

CONCLUSION

Conversational theory is built up from stringent definitions of commonly used terms such as understanding and memory. It is associated with a system of learning in which the subject matter is broken down into its basic elements and reconstructed into an arrangement of topics which provides a 'map' for the student. Rules cover the transactions made within the system, but the student is able to follow different paths and obtain various demonstrations before testing his own understanding of topics. He is also free to adopt his own learning strategy within defined limits.

It is possible to view other experiments on learning as approximating to the conditions described here. For example, in TEACHBACK the student is involved in free learning, exploratory behaviour, and is guided by a neutral onlooker. The experiments of Luria and Piaget follow a similar approach, but lack the demands for proof of understanding built into the standard condition of conversational theory. Of course, the test of the theory will be in its explanatory power, on the one hand, and in its effectiveness in bringing about understanding on the other. Some indication of explanatory power has already been given and a subsequent paper will provide evidence of the effectiveness of the systems so far developed, in which students learn, understand and remember complex subject matters.

ACKNOWLEDGMENTS—The research reported in this paper is supported by the SSRC under Research Programme HR 2708/2: "Learning Styles, Educational Strategies and Representations of Knowledge; Methods and Applications."

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(*Manuscript received 14th April, 1975*)